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Best Practices to request
and exploit Digital Twins
and Lifecycle OTS

An Inprocess Whitepaper by JoseMaria Ferrer

10 Best Practices to request and exploit Digital Twins and Lifecycle OTS

Abstract

Operator Training Simulators (OTS) have become an integral element of the Operator Competency Development Programs of the process industry. The dynamic simulation technology has evolved from the early days, incorporating new training functionalities and communication capabilities. On the other side, modern Integrated Control and Safety Systems (ICSS) include independent soft-controller tools to allow an exhaustive check-out of the ICSS and the OTS development. This has enabled flexible and customizable OTS architectures, which reduces significantly the development costs and maximizes the value of the OTS investment. The main focus of this article is to provide recommendations and advices to Operating Companies (OpCo) and Engineering Procurement & Construction (EPC) Companies when they embark in a tender process to procure an OTS.

Introduction

In the last decade, there has been a growing adoption of Operator Training Simulators (OTS) by Operating Companies (OpCo) from the Oil&Gas to the Chemical industry. The reasons for that are:

- **Increased complexity of ICSS:** Modern Integrated Control and Safety Systems (ICSS) are heavily based in software applications used to configure the database module blocks. The need to deeply checkout that ICSS databases before the start-up is key to avoid unnecessary delays or incidents.
- **Tight schedules:** Market pressure imposes tight project schedules to advance the First Oil date or

to minimize the time-to-market. This leaves less time to train operators, who need to be intensively trained before start-up.

- **Enhanced value:** Some companies have exploited their OTS value beyond the traditional Operator Training purpose, maximizing the return of their investment. This extra value is explained in the Lifecycle OTS section.
- **Lower cost:** PC-based architectures have dramatically decreased the hardware cost to only 2-5% of the total cost. Out of the box ICSS emulators (also called Soft-Controllers) with open communication standards (OPC) have enabled flexible and customizable OTS architectures while reusing the dynamic process models developed for the engineering design phase reduces the development costs significantly.
- **Multiple providers:** Specialized OTS vendors, independent from the ICSS vendor, have democratized the OTS business by allowing the customer to define their own process simulation preferences and lifecycle modelling plans.

Multiple success cases [1, 2, 3] and industry surveys [4] emphasize the added value of an OTS. Nevertheless, few articles [5, 6] provide guidance on how to successfully complete this task and most importantly, how to extract all the potential value of our OTS investment. Therefore, the aim of this article is to provide key practical advices to OpCos and EPCs during the OTS tendering process and highlight the best practices to make the Lifecycle Modelling approach feasible in order to further increase its added value and potential applications.

Lifecycle OTS concept

The Lifecycle modelling approach was initially introduced by Hyprotech during the late 90's [7]. The "One model, many uses" concept could be misinterpreted, creating unrealistic expectations. Simulation models are often created with a single purpose in mind, leaving other potential applications unexploited.

Enterprise Resource Planning (ERPs), like SAP or others, is a simile which can be used to explain the Lifecycle OTS. ERPs were founded on simple premises:

- Data in just one place
- Interdepartmental data accessibility
- Standardize work processes

imilarly, lifecycle modelling is focused to keep the process models as reusable and accessible as possible. This fact minimizes the re-entered data, avoids model duplications and maximizes the number of users.

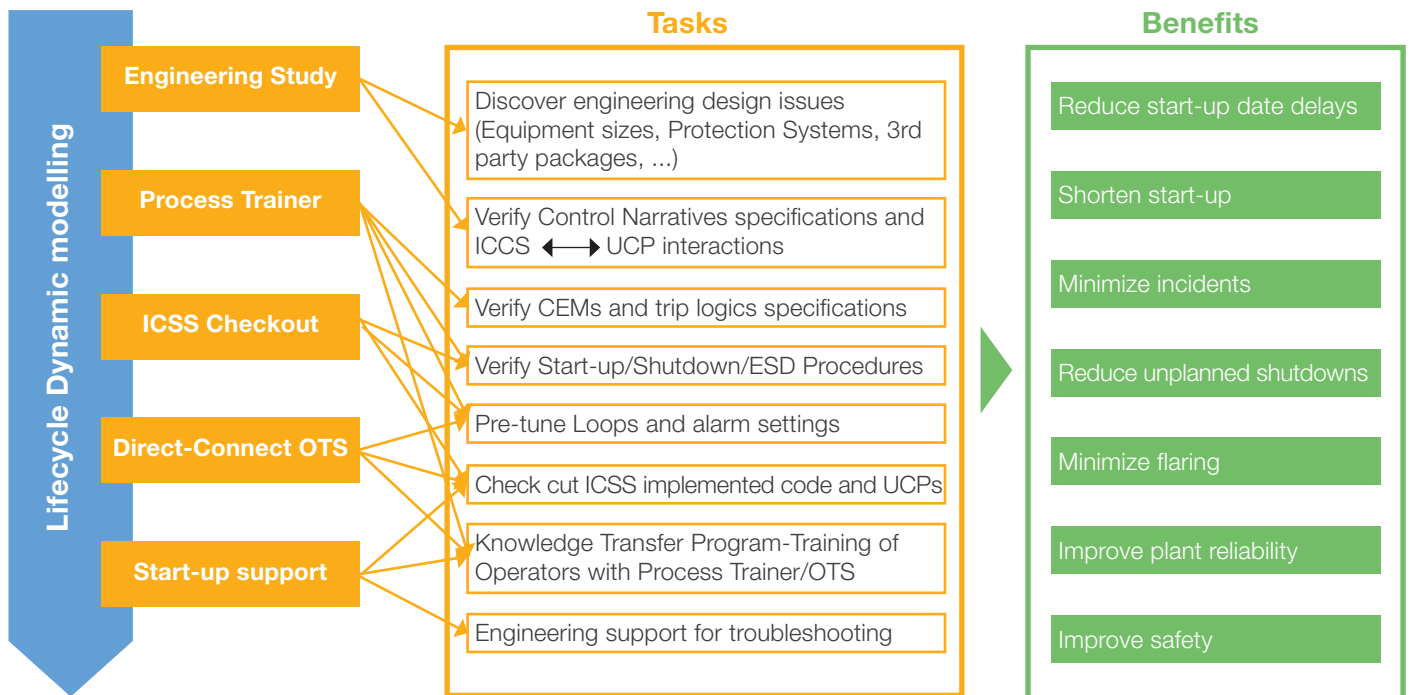
Lifecycle modelling aims to use a common simulation software tool, from design to operations. Process plants are designed using Steady-State process simulation tools (time dependency is not considered, all Heat & Material balances are closed) created along the 80s-90s (HYSIM, Aspen+, Pro-II) [8, 9]. However, the plants will operate in the real world where the time variable exists and all process variables change with the time. Therefore, a Dynamic process simulation tool is needed.

In the late 90's, Hyprotech launched a process simulation tool (called "HYSYS Process" and "HYSYS Dynamics") which was able to run within the same application software in two different modes: Steady-State and Dynamics. This was the first milestone in the lifecycle modelling vision: to have an application which combined the steady-state process models developed for the design of the plant with the dynamic process models to control and operate the plant. Sharing the same thermodynamic packages, component lists, process layout, equipment naming and data, etc. All using the same HYSYS graphical user interface that was proven to be very user friendly and interactive.

At the beginning of the 21st century, Hyprotech was acquired by Aspentech and since then, the application is commercialized under the name of "Aspen HYSYS" and "Aspen HYSYS Dynamics", incorporating natively all pure components and thermodynamic packages of Aspen Properties.

With such a software available for the dynamic process modelling of the plant, users can fully exploit the value of each phase of an OTS lifecycle modelling approach:

- **Phase 1** Process Design and Control validation: Plants are designed in Steady-State and a number of assumptions are taken at this stage. For example, pressure drops are specified in each valve but in real operation this depends on flow, installed valve characteristic, %opening, upstream and downstream pressures, hydrostatic effects, etc. This explains why many control valves are positioned in real plant operation at 20% or 80% opening, when they were designed to operate at 50%. Dynamic process models offer the possibility to realistically study critical transient scenarios to ensure that the designed processes are safe and operable.
- **Phase 2** Process Trainer and procedure validation: As soon as the dynamic model is built, it can be used to create a Process Trainer (or Early-OTS), without having the need to wait for the final release of the ICSS database. An early OTS offers the possibility to design and test all the operating procedures before they are written in the plant Operating Procedures Manuals, or programmed in the ICSS. Additionally, it allows an early operator training, with more focus in understanding the process and how it should be handled. At this stage, Senior Control Room Operators can provide invaluable feedback for the design of the Operating Procedures and the definition of the trip and alarm settings.
- **Phase 3** ICSS Checkout: Performing the ICSS checkout using the dynamic process model allows a deeper and realistic checkout of all the implemented control narratives, loop tuning, sequences, interlocks, alarms, safety logics, etc. This reduces significantly the start-up time, controllability issues, false trip occurrences or potential equipment damages.
- **Phase 4** Operator Training: Exposing the operators to trip scenarios, specific operating procedures, disturbances and uncommon operations in a simulation environment using the same ICSS and HMI they will use in the control room, provides the most realistic and efficient training. This phase improves the controllability and operability of the plant, increases its safety, minimizes incidents, reduces potential flaring and speeds-up planned start-ups and shutdown times.
- **Phase 5** Start-up and operation support: The engineers who have been developing the OTS have deep understanding of the process, operating procedures, ICSS operation, control narratives, etc. With the help of the dynamic process models they provide a vital assistance in the start-up of the plant, troubleshooting process or control issues and optimizing the process at stable conditions.



Process simulation software used for the lifecycle OTS should contain the following characteristics:

- **Model Consistency:** Thermodynamic packages consistent with steady state design models. Data is introduced once and the model is used along all phases of the lifecycle.
- **Growing Detail/Scope:** Detailed equipment data is available and refined as the project evolves. Additional process units can be incorporated as needed in the application.
- **Rigor:** CRO's will expect realistic process responses from the models. This is key to replicate/verify/improve operating procedures, tune controllers and define alarm limits.

- **Extrapolation:** Extrapolate process conditions far from nominal. Model will help to determine the settings to maximize production, reduce flaring and improve its control.
- **Reusability:** The dynamic model can be re-used with minor modifications for other purposes.
- **Maintainability:** Models are inherently easy to maintain.

Let's review the 10 best practices to request and exploit a lifecycle OTS. Not a thoroughly dissertation about all the details to create an OTS tender but to provide key common-sense hints to customers.



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1 Break free

Every OpCo, EPC and Licensor has their own process simulation preferences. Many man-hours and other resources have been invested in learning this specific software, in developing the process models and even in creating internal property packages or custom unit operations.

Consequently, if a company has standardized the usage of a specific simulation software (e.g. Aspen HYSYS), it should be able to request/demand an OTS using the same simulation engine and not be limited to the process simulation tools offered by the ICSS vendors.

Frequently, ICSS vendors tend to install the Main Automation Contractor (MAC) schemes in new projects and constrain the customers to acquire the OTS exclusively from them, without giving any

option to the EPC or OpCo to freely decide what process simulation software they prefer to use in their OTS.

By decoupling the OTS from the MAC, or by specifying your preferred process simulation software, you are securing the quality of the most important component of the OTS: The Simulation Engine. Therefore, you are selecting the process simulation software based on best standards rather than a low-fidelity process simulator that some ICSS vendors are enclosing together with their ICSS. Specifying your preferred lifecycle high-fidelity process simulation software, your OTS will be able to realistically reproduce plant conditions. This enables better training scenarios and gains the operator's credibility, which results in a safer plant operation.

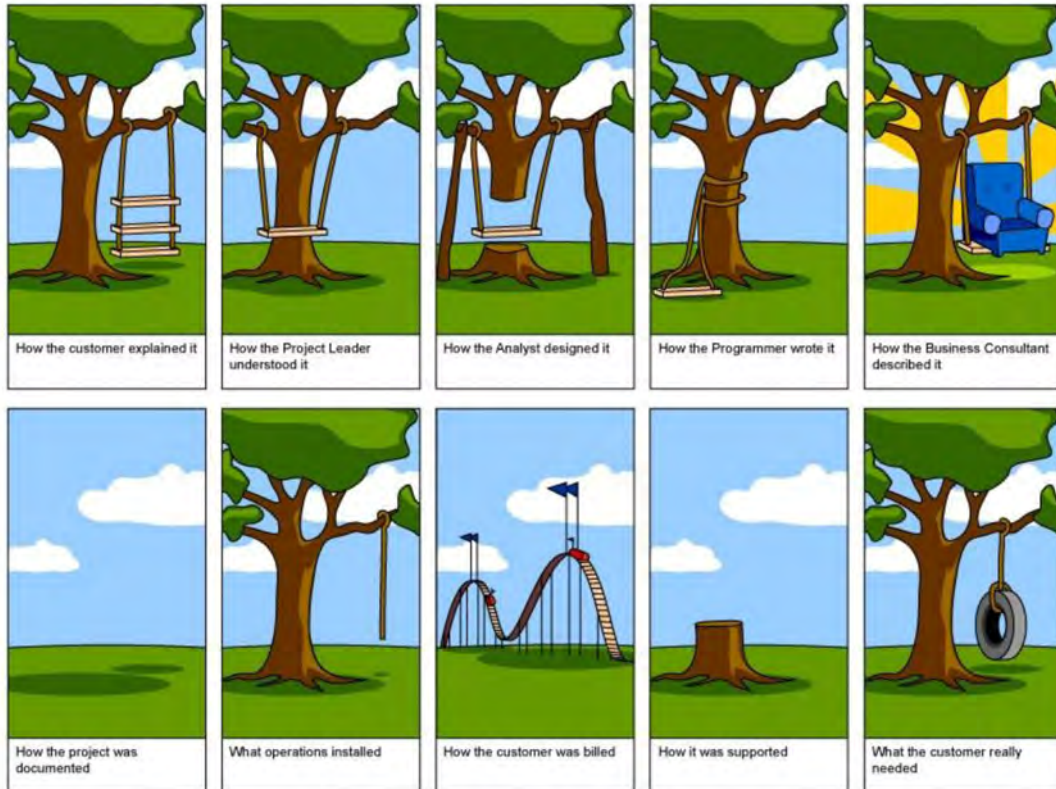


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2 Analyze what you really need

There are two types of OTSs: Direct-Connect (also known as Stimulated) and Emulated. You need to analyze which one suits better your training needs. For new plants or major revamps, a Direct-Connect OTS solution is recommended, since there are huge benefits in performing a deep ICSS database checkout using first principle models. ICSS schedule is frequently shifted, affecting the development of the Direct-Connect OTS and compromising the planned training time. Therefore, the recommendation is to start with an “Early OTS” (Emulated OTS) focused on the process and used for early training purposes and for Operating Procedures definition. As the emulated OTS and the Direct-Connect use the same first principle dynamic models, the cost of including an “Early OTS” is minimal.

For existing plants with budget limitations, an Emulated OTS solution could be considered, since its complexity is lower in terms of ICSS hardware

and software emulation. Moreover, some old ICSS systems do not have an associated ICSS emulator software, being the Emulated OTS the only available option.

There are also external packages like compressors, turbo-expanders, turbines, etc, which are controlled using PLCs provided by specific equipment manufacturers. Frequently, a manufacturer emulation software does not exist, and its implementation needs to be performed within the process simulator.

OTSs are a mix of rigor, detail and performance. All of them need to be balanced. Don't request low-value features (like asking more than x5 acceleration factor) which will artificially increase the number of CPUs required or will reduce the rigor and detail of the process model. Review the “bells and whistles” which are really needed [10].



3 Take the pan by the handle (Spanish saying)

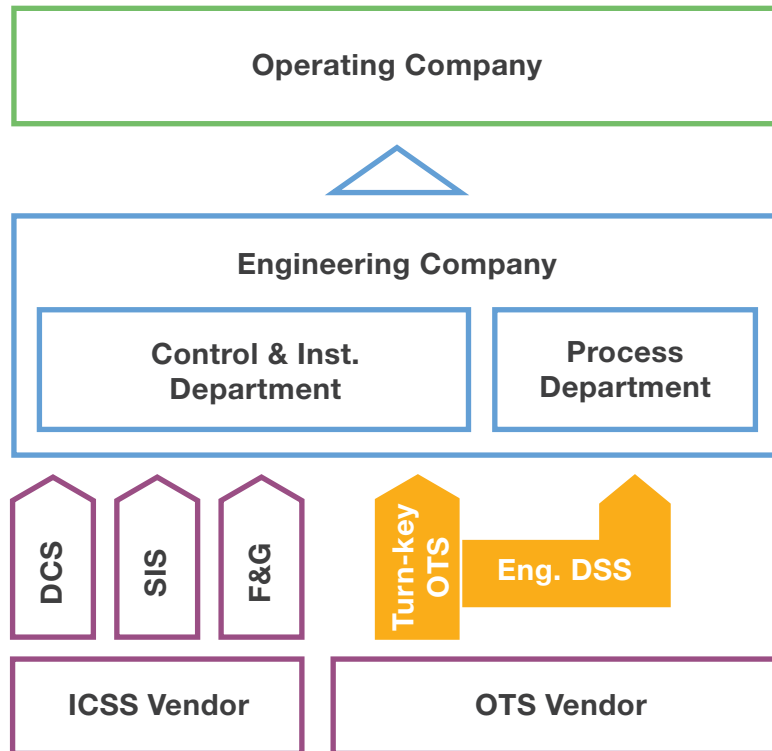
When an OpCo or an EPC is requesting an ICSS, they should also define the ICSS details together with all the ICSS hardware and software components required to develop the OTS internally, or with the help of a third party OTS vendor. In Spain we say “tener la sartén por el mango” (ie. you call the shots), which means that you are the owner of the buying process and you put your own conditions.

Some ICSS vendors adopt very aggressive commercial strategies when the OTS is not acquired together with the ICSS or when their process simulation software is not chosen. In order to properly compare all the ICSS offers, the buyer should carefully detail in the ICSS tender all the Hardware and Software required to implement the OTS independently from the ICSS vendor. As shown below:

- Hardware for X Operator Console Stations including monitors, keyboards, etc
- Software for X Operator Console Stations
- Software for ICSS emulator (Control system)
- Software for ICSS emulator (Safety system)
- Any ICSS emulator communication layer required to connect to a 3rd party simulator.
- Maintenance costs of above software
- A number of hours to implement the ICSS punch list coming from the ICSS checkout with the OTS

With these tabulated prices in mind for every ICSS bidder, the buyer can then prepare a separate tender for the OTS stating that all ICSS Hardware & Software will be provided by the buyer. This allows for a more competitive OTS tender process.

Do this before you award the ICSS, otherwise you will be virtually tied to one OTS supplier.



4 Don't pay twice

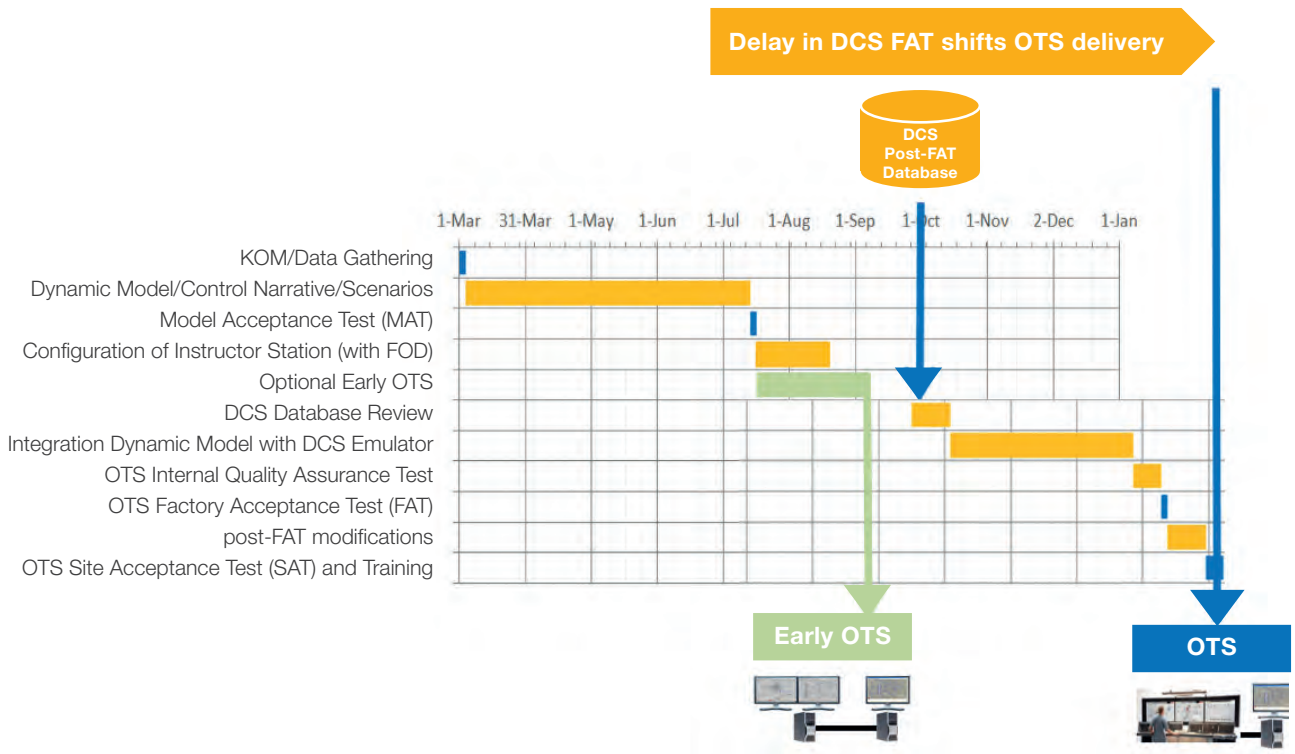
Process Departments usually require and request detailed Dynamic Simulation Studies (DSS) for the critical areas of the plant. If at certain point the Control & Instrumentation department requests a completely separated OTS, the result is a duplication of the simulation efforts and costs.

By basing the OTS on an engineering simulation software, the DSS could be included within the OTS scope and thus, achieve significant time and cost savings.

It is true that the model required for the DSS might use smaller step-size resolution or additional level

of detail. However, the DSS and the OTS have in common around 80% of the modelling work as both require the verification and implementation of the control narrative, safety logic specifications, automatic sequences and operating procedures. [11]

In addition, performing an OTS based on an engineering tool enables the possibility to obtain a standalone version of the dynamic model with all control loops simulated within the model, which can be used directly by Process Engineers, Control Engineers and Operations support engineers.



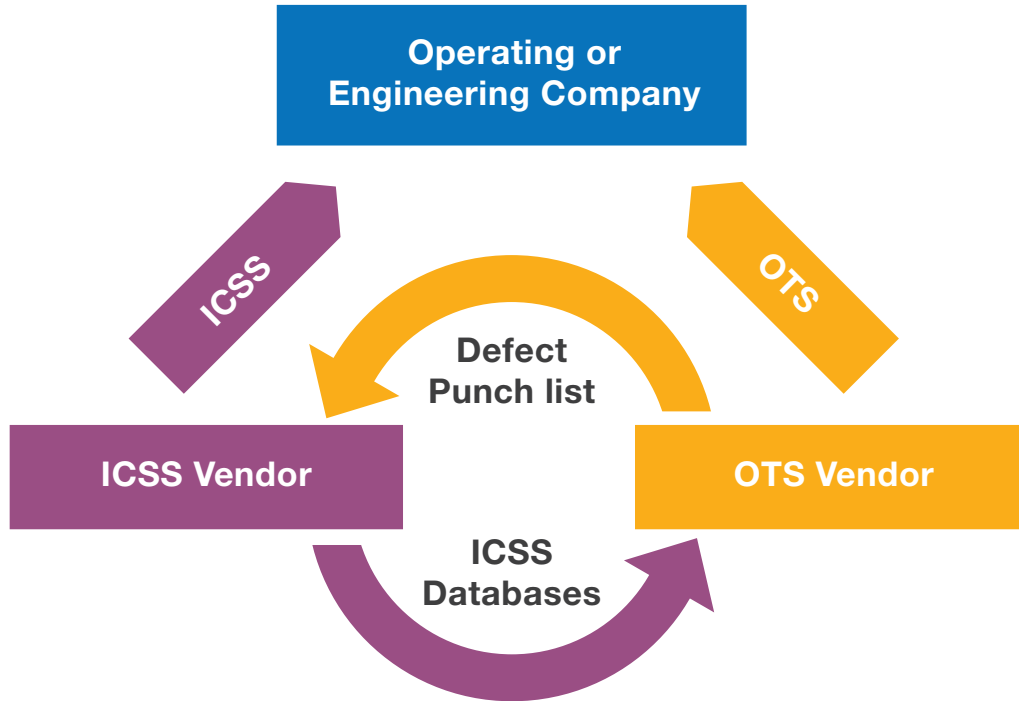
5 Train Earlier

Ideally, the OTS should be delivered 6 months before Start-up in order to concede sufficient time to train the Control Room Operators (CRO) in advance. Nevertheless, the delivery of ICSS database is frequently delayed or in other cases the start-up date is re-scheduled to an earlier date for business reasons. These facts reduce considerably the training time available with a Direct-Connect OTS solution and affects the operator’s availability, as near the start-up date the operators have higher workloads.

In order to alleviate this effect, an additional Emulated OTS can be supplied to provide an early operator training, more focused in the process understanding,

control logic definition and interactions, and the validation of the plant Operating Procedures. Early knowledge transfer in a simulation environment is especially valuable for plants with external PLC packages (e.g. compressors, turbines, etc.) that interact with the main ICSS of the plant or whenever the combined Start-up, Shutdown and Emergency Shutdown procedures need to be coordinated between two or more independent control systems.

Since the Emulated OTS is independent of any ICSS hardware or software, it can be easily replicated in standard PCs, allowing parallel training for large groups of operators.



6 Plan for extensive ICSS checkout

ICSS configuration code for new plants is massive, and like all codes, it will contain errors or defects. Sometimes, a small defect can derive into catastrophic consequences. Some industries, like aviation or nuclear, have specific protocols to verify every single line of code in the system.

The ICSS FAT and SAT stages might find a significant number of defects. However, as these procedures lack a realistic feedback from the plant, many defects will remain undetected until the commissioning and start-up phase, causing significant delays and efforts to find, analyze and solve any problem encountered. There are two kinds of defects in the ICSS databases:

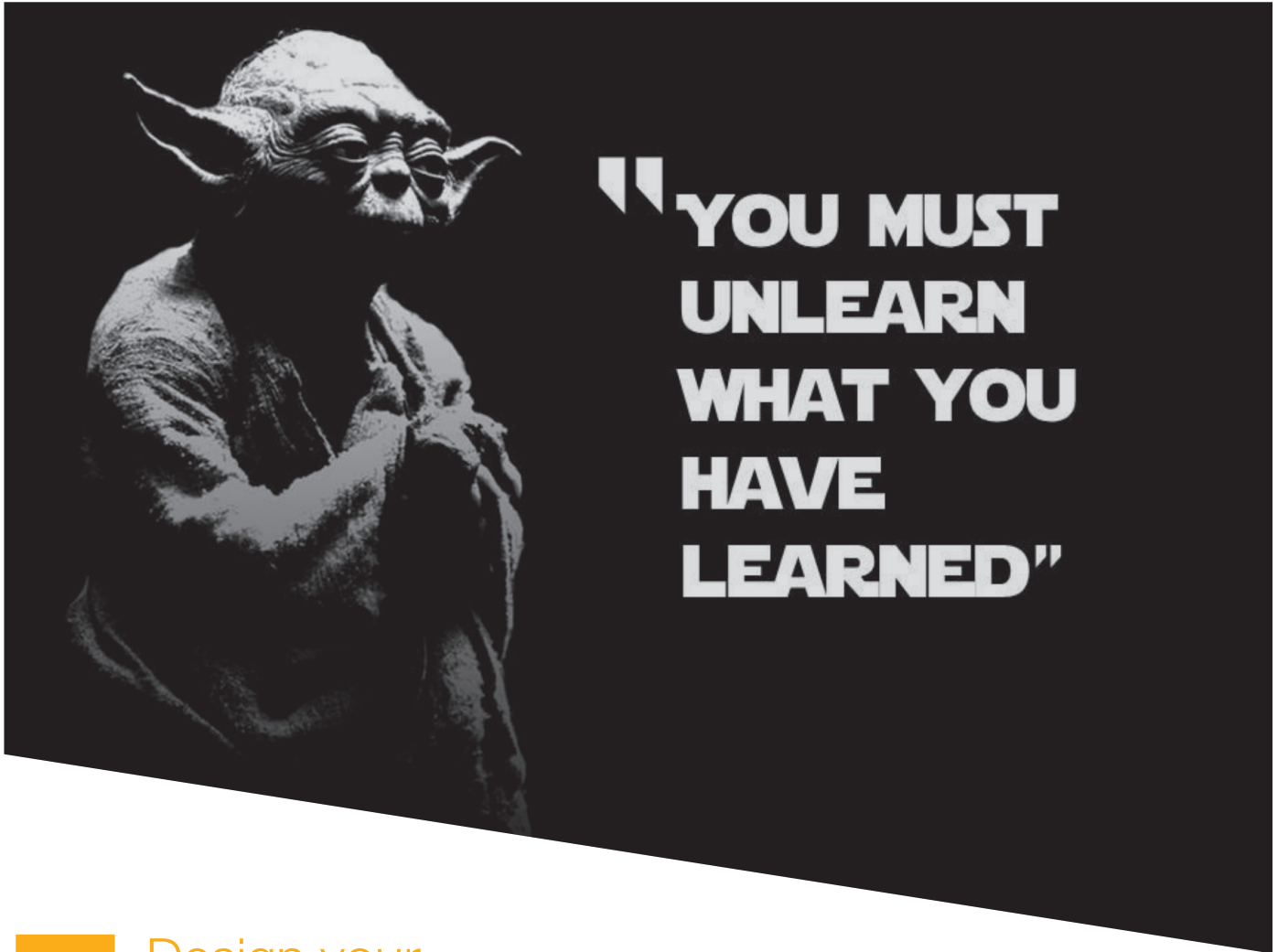
- Specification defects (when things are correctly coded but they are wrong in nature)
- Implementation defects (when it is not configured as specified).

In addition, it should be noted that ICSS databases are configured by automation engineers who know

well the ICSS functions but frequently don't know anything of the process itself. Consequently, they will not be able to identify the "specification defects" which will only appear during start-up.

The use of a dynamic model to deeply test and checkout the ICSS database, the controllability of the process and the overall plant operability will reveal many hidden issues. This item must be clearly stated in OTS tender. In such cases, the OTS vendor who knows well both, the process model and control narratives, will be able to act as an external auditor of the ICSS database before the start-up.

If the OTS is developed by the ICSS vendor there could be a conflict of interests within the company and potential issues could not be brought to the customer. The interest of the ICSS vendor is to pass their ICSS FAT/SAT milestones, not to bring up every process control narrative specification flaw. [12, 13]



7 Design your training program

The OTS alone doesn't do the training, it requires a proper companion training program. Sometimes it is surprising to see multimillion dollar investments in OTS without dedicating enough resources to design, execute and maintain a training program within the company.

One important aspect when requesting an OTS is to define the set of training scenarios that will be included in the system. This is not an easy task, since it requires to analyze not only the normal operating procedures (Start-up, Shutdown, Load change, Feed change) but also all the key abnormal and emergency conditions that the plant could suffer during its life (Equipment anomaly or trip, Loss power/utilities, plant disturbances, etc.). Experienced senior operators and specialized OTS suppliers can advise the client in the generation of an appropriate list of training scenarios, many of them could also be part of the DSS scenarios executed in the engineering verification phase. This initial set of training scenarios will be for sure expanded

after the plant start-up and subsequent years of operation, since new incidents and issues will require the awareness and training of all operators as well as properly scheduled refresher training.

Every training scenario implemented in the OTS should include a training objective, a description of the events and factors (Safety, Quality, Environmental, etc.) to be taken into account by the operator being trained, the expected operator responses and the performance indicators that will be used to evaluate the operator's actions during the exercise.

The OpCo needs to design their operator competency programs considering the OTS as an integral tool of the training programs. Specialized OTS vendors can support its design and integrate the training programs and the OTS. Resources and workflows need to be defined and budgeted in order to keep the training programs and the OTS updated with the plant changes.



8 Exploit models

Using an engineering simulation tool to develop the OTS dynamic process model is key to obtain increased benefits from the OTS beyond operator training. Once the dynamic model is built and validated against the H&MB or plant data, it is integrated within the OTS system. However, an independent copy of the dynamic model (self-containing all control loops) can be easily generated to be used by the engineering teams directly from their own desktops. This deliverable can be requested in the OTS tender and can be supplied after OTS' Model Acceptance Test. This model can be used by:

- **Process and HSE engineers:** To support HAZOP studies, process pressure-flow related issues (not captured by Steady-State models), or calculate realistic relief loads in safety scenarios. [14]

- **Process Control engineers:** To study alternative loop configurations, verify the accuracy of inferentials or generate seed models for APC. [15,16]
- **Plant engineers:** To analyze the impact of other feedstocks, replicate plant issues, study new operating procedures or find ways to increase plant profitability.

Of course, this would require the training of all these engineers in the usage of dynamic simulation tools and the nomination of some of them as key leaders in their own department groups.

Just after the Model Acceptance Test, specialized OTS vendors can provide customized simulation courses to transfer the dynamic modelling know-how and assist customers to exploit its value in other areas.



9 Secure sustainability

Industry surveys indicate that many OTSs are not properly maintained after the start-up. This causes a loss of confidence from the operators, as the training exercises do not reflect the last process or control changes. The OTS starts to be less usable as the plant diverges from the model, which makes the training sessions less effective and frequent. Engineers also find less value in the model since it doesn't reflect actual plant configuration and conditions, because they cannot afford the time to update it.

Therefore, a complete OTS maintenance program needs to be requested in the tender, defining how the process and ICSS changes will be routinely updated in the OTS. This will require to establish certain work processes within the company and define new roles (OTS Engineer, Dynamic Simulation Engineer) that didn't exist before. Companies need to think about it before requesting an OTS.

Using an engineering simulation tool as the OTS engine helps companies to self-maintain their OTS, since they have the required internal expertise in those tools. It will be easier to introduce process changes into the models and reduce the dependency on the OTS vendor for every single process change.

Each company should define the level of self-sufficiency they want for the maintenance of their OTS, balancing between the development of its internal expertise and the maintenance services provided by OTS vendors. Whatever combination is chosen, it needs to keep the OTS updated as in the real plant and proactively expand the training scenarios with the lessons learned each year. By keeping the OTS updated, the companies are not only extending the life of their OTS, but are also allowing engineers to continue extracting engineering usages from the model.

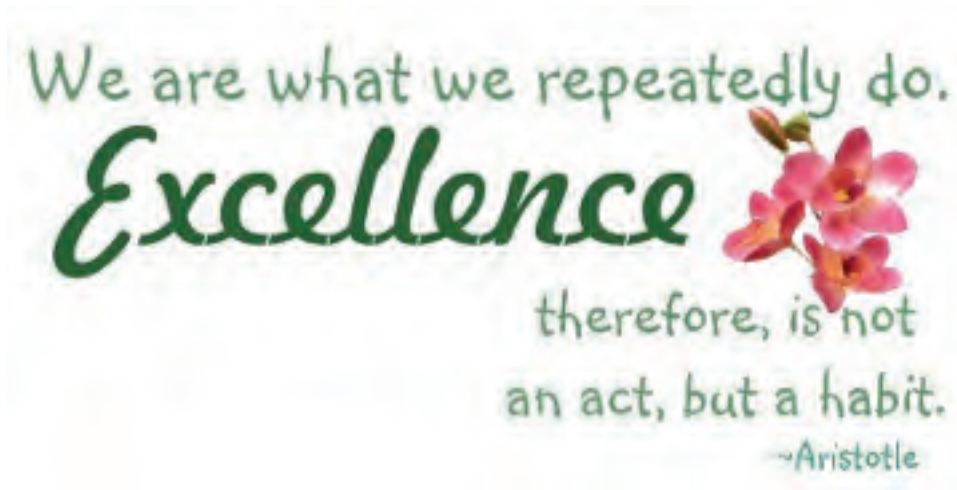


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10 Look for excellence

Building a high fidelity dynamic simulation model is a very different task than configuring an ICSS system. You need dynamic modelling experts to efficiently build a reliable dynamic model for the OTS. By assigning the development of the OTS to a group of dynamic modelling experts you are selecting for excellence rather than just tacking on a must- have to a contractor focused elsewhere.

A dynamic modelling team, independent from the ICSS configuration and delivery, can be extremely agile to changes in operating objectives, control narrative, process equipment, staffing plans or project schedule.

Sometimes, it is believed that by including the OTS within the ICSS scope, the process model building is going to be executed by the same group who is going to code and configure the ICSS. But typically, those groups belong to different departments, locations or distinct time zones and tend to work as

silos within the same company. Customers should put special attention about how these two groups work together, since sometimes they obey to different sub-project goals, not necessarily aligned with customer objectives.

Specialized OTS vendors not only provide the best-in-class simulation and OTS technologies but also create rigorous models which are easy to visualize and maintain. Moreover, the customer can be included in the OTS team to maximize the modelling knowledge transfer and to allow customer's engineers to fully exploit and maintain the value of those models.

Every customer is unique, with their own products, processes, simulation technologies, training approaches, schedule challenges, company policies and budgetary constraints. It is the OTS supplier who should be flexible enough to fulfil the customer needs and provide the most valuable solution.

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